

# AMBER - A New System Simulation Framework for SMART Mobility



**AYMERIC ROUSSEAU, PAUL DELAUGHTER, MICHAEL JUSKIEWICZ,  
SYLVAIN PAGERIT, PHILLIP SHARER**

**2017 DOE Hydrogen Program and Vehicle Technologies  
Annual Merit Review**

June 7, 2016

# Project Overview

Timeline	Barriers
<ul style="list-style-type: none"><li>• Project start date : FY16</li><li>• Project end date : FY18</li><li>• Percent complete : 60%</li></ul>	<ul style="list-style-type: none"><li>• Bring technologies to market faster</li><li>• Integrate a diverse set of simulation tools</li><li>• Accelerate technology evaluation</li></ul>
Budget	Partners
<ul style="list-style-type: none"><li>• FY16 Funding : \$600K</li><li>• FY17 Funding : \$600K</li></ul>	<ul style="list-style-type: none"><li>• Feedbacks from current Autonomie users (&gt;200 institutions)</li><li>• Specific discussions with few OEMs including Ford &amp; GM</li></ul>

# Project Relevance

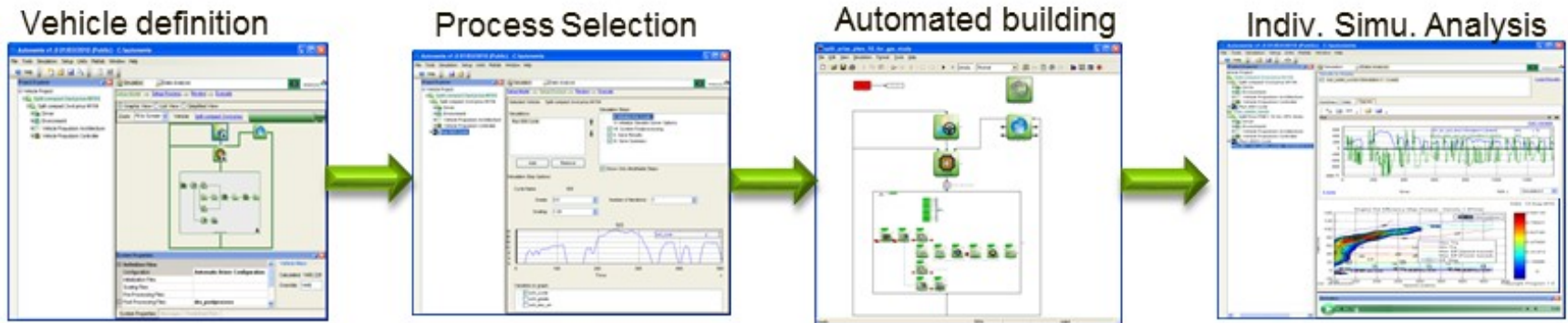
**As Mobility becomes Smarter, our Tools have to become Smarter.**

- The increased number of vehicle technology options (powertrains, components...) requires an increasingly large number of simulations
- The rise of connectivity and automation requires a new system approach including multiple vehicles operating in their environments
- Existing vehicle system simulation tool have focused on individual vehicles while transportation system simulation tools have not considered vehicle energy
- A new approach is required to continue to support DOE VTO R&D activities (I.e., Smart Mobility, technology benefit analysis...) and the system modeling community.

# Project Relevance

## The Existing Autonomie Workflow is Single Vehicle Focused

- Highly successful workflow when customizing a single vehicle.
  - All aspects of the vehicle can be easily modified through the User Interface
- Great for small scale studies involving 10 or 20 vehicles
- Not capable to handle large scale studies or Smart Mobility workflows



**Existing Tool (Autonomie) - Current Workflow Focused on Few Individual Vehicles**

# Project Relevance

## AMBER Satisfies the Critical Need to Integrate Existing Tools into Coherent Workflows to Tackle the HPC Studies of Tomorrow

- Workflow Spectrum: simulation of individual components to large metropolitan areas.
- New Workflows require Large Scale Simulations (HPC)
  - NHTSA study requires 100,000s of vehicles
  - Smart Mobility simulations over metropolitan areas require simulation over 1,000,000 of cycles
  - Smart Mobility requires linking tools such as POLARIS (EEMS014) with vehicle modeling tools such as Autonomie (VAN023)
- OEMS need to manage and simulate vehicle calibrations across a wide range of MBSE workflows from single vehicle to large scale
- New Workflow Supports Industry's R&D Direction

# New Workflow Supports industry's R&D Direction

Process Selection



Run Process



Specific  
Post-processing

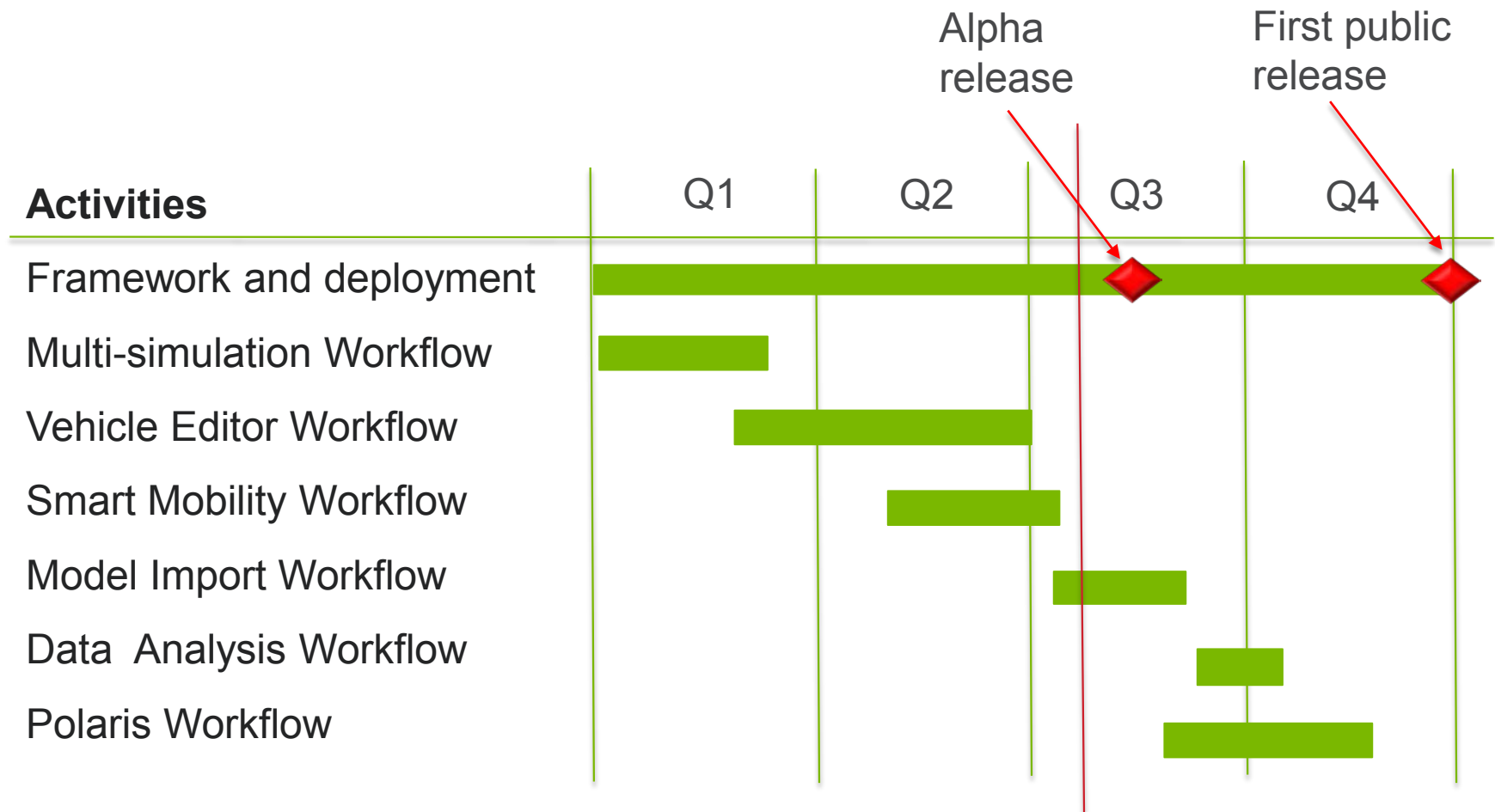
Users: select n vehicles on run cycles, change parameters, import test data...

Developers: Build new vehicle, build new process, import new test data format, setup HPC...

- Select 10 vehicles on 10 cycles with control parameter optimization on HPC
- Import APRF test data
- Vehicle powertrain sizing to match performance
- ...

- Individual vehicle analysis
- Database analysis for large scale simulations
- No analysis (i.e., test data import)
- ...

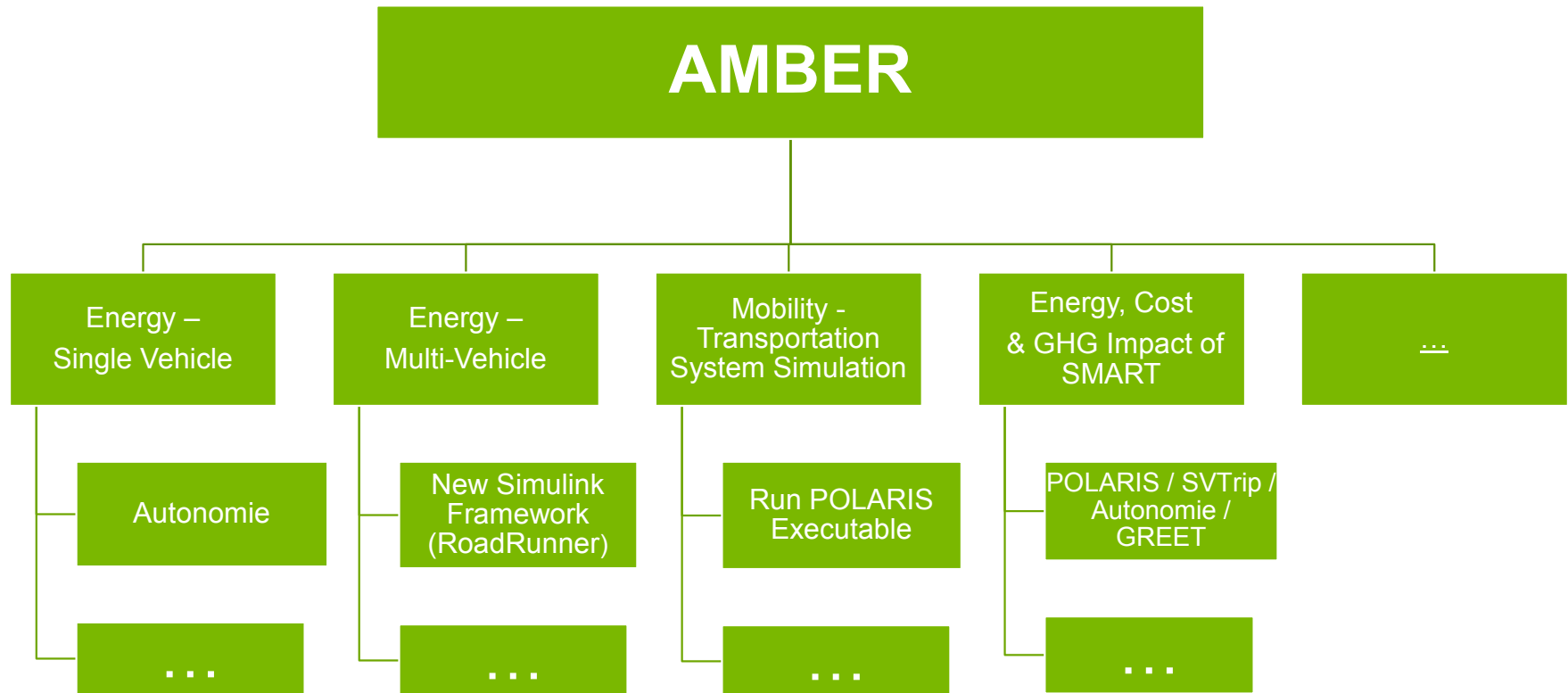
# Project Milestones



# Approach

Integrate Existing & Develop New EEMS Processes into AMBER

AMBER: Advanced Model Based Engineering Resource



But each of these steps are multiple workflow as well...

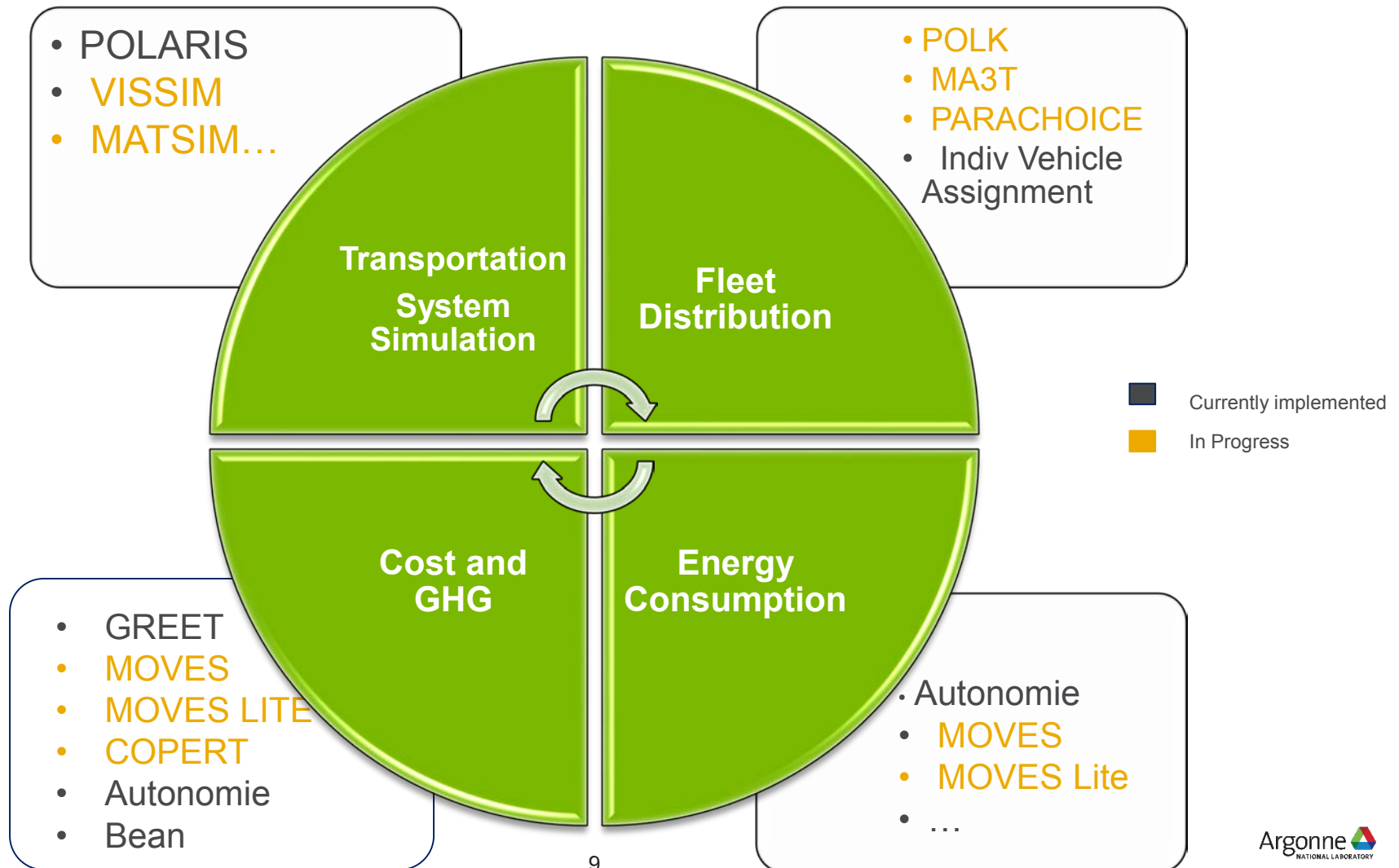
- Currently implemented / in Progress
- Future Vision



# Approach

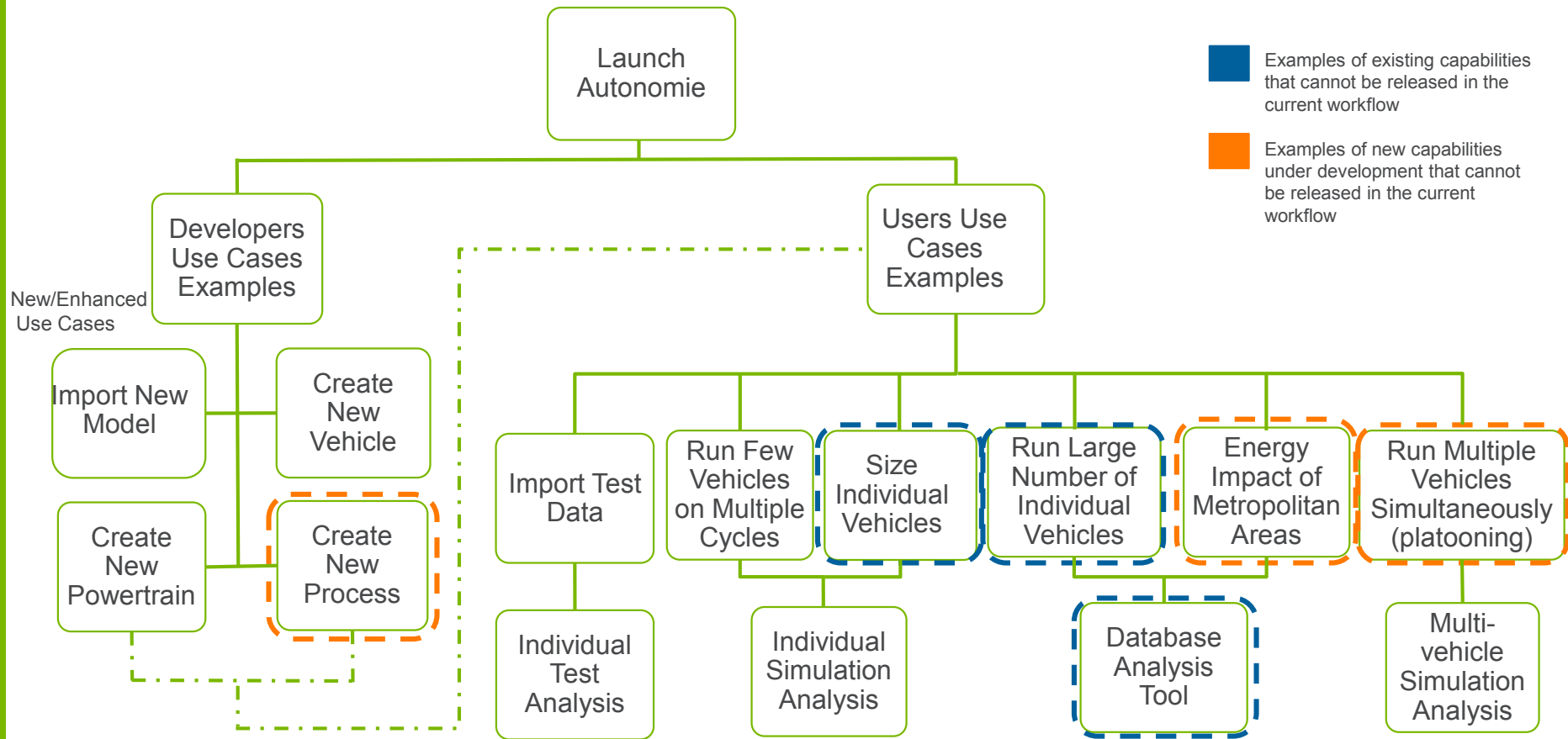
To Maximize Reusability and Collaboration between Researchers, Our Vision is to Generalize ANY Workflow with AMBER

AMBER: Advanced Model Based Engineering Resource



# Approach

## AMBER will Allow Deployment of Existing Workflows and Separate Users from Developers



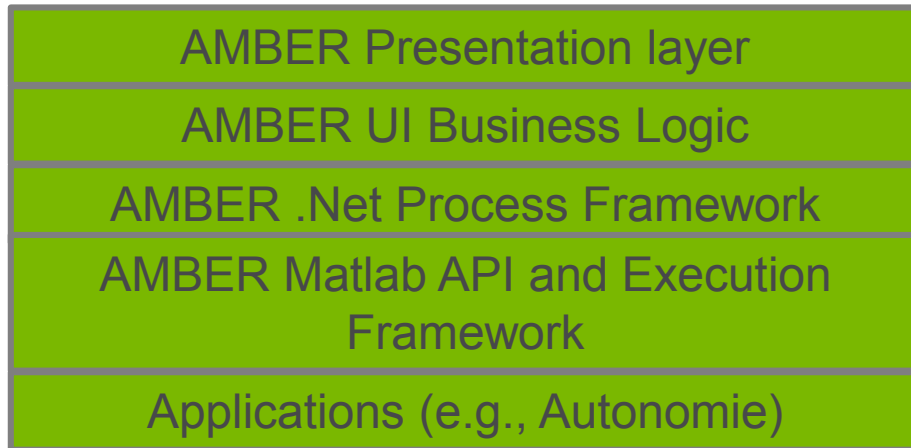
=> New platform will enable dissemination of existing and new capabilities to the entire user community as well as streamline Argonne internal processes

# Technical Accomplishments

## A Multilayered Approach was Selected to Allow Different Levels of Customization by Users



Developed a framework that will allow users to integrate many diverse tools into workflows



User's can implement their own custom UIs

The UI interfaces are open allowing users to plug their own custom UI into existing BL

UIs can be reused and combined together by the framework layer

Users create their own scripts and Workflows in Matlab using the API to design their own complex simulation logic on top of existing work

Users can use our applications or provide their own.

\*Also follows industry best practices

# Technical Accomplishments

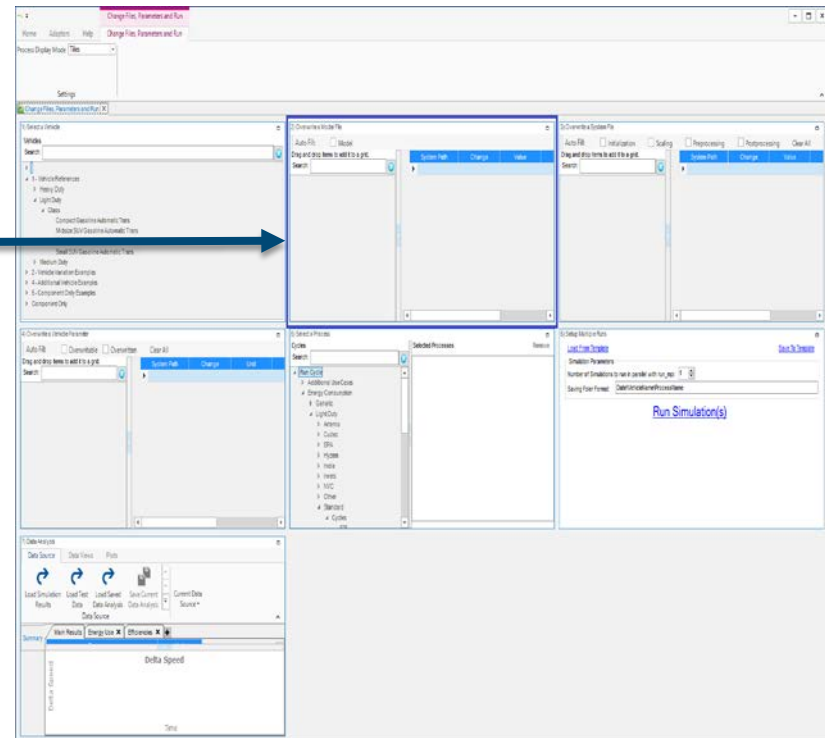
## Customizing the Workflow is Easy



Workflows are built from xml analogous to how we build vehicle models

- Steps in the xml correspond to tabs in the UI
- Don't need a step, just remove it from the xml

```
<?xml version="1.0" encoding="utf-8" standalone="yes"?>
<Process Key="SingleRunWithSystemFileParameterOverride" IsTopLevel="true" DisplayOrder="4" Group="User" Name="SingleRunWithS
<Version Author="Antonomic" Date="2012-12-10T23:14:31.413074-06:00" Version="" />
<Property Name="Application" Value="Fuel Consumption and Performance" />
<Pre Key="select_vehicle" Name="select_vehicle" FileName="select_vehicle.a_prestep">
  <Editor>
    <Component Class_Name="Antonomic.Core.VehicleApplication.Editors.VehicleSelection.NRShareVehicleSelection" />
    <Control Class_Name="Antonomic.Presentation.VehicleApplication.Editors.VehicleSelection.NRShareVehicleSelection" />
  </Editor>
</Pre>
<Pre Key="overwrite_model" Name="overwrite_model" FileName="overwrite_model.a_prestep">
  <Editor>
    <Component Class_Name="Antonomic.Core.VehicleApplication.Editors.ModelFileOverride.NRShareModelFileOverride" />
    <Control Class_Name="Antonomic.Presentation.VehicleApplication.Editors.ModelFileOverride.NRShareModelFileOverride" />
  </Editor>
</Pre>
<Pre Key="overwrite_file" Name="overwrite_file" FileName="overwrite_file.a_prestep">
  <Editor>
    <Component Class_Name="Antonomic.Core.VehicleApplication.Editors.SystemFileOverride.NRShareSystemFileOverride" />
    <Control Class_Name="Antonomic.Presentation.VehicleApplication.Editors.SystemFileOverride.NRShareSystemFileOverride" />
  </Editor>
</Pre>
<Pre Key="overwrite_parameter" Name="overwrite_parameter" FileName="overwrite_parameter.a_prestep">
  <Editor>
    <Component Class_Name="Antonomic.Core.VehicleApplication.Editors.ParameterOverride.NRShareParameterOverride" />
    <Control Class_Name="Antonomic.Presentation.VehicleApplication.Editors.ParameterOverride.NRShareParameterOverride" />
  </Editor>
</Pre>
<Pre Key="select_process" Name="select_process" FileName="select_process.a_prestep">
  <Editor>
    <Component Class_Name="Antonomic.Core.VehicleApplication.Editors.ProcessSelection.NRShareProcessSelection" />
    <Control Class_Name="Antonomic.Presentation.VehicleApplication.Editors.ProcessSelection.NRShareProcessSelection" />
  </Editor>
</Pre>
<Process Key="pxfProcessRunMultipleVehicles" Name="start_vehicle_simulation" FileName="pxfProcessRunMultipleVehicles.a_process
  <Editor>
```

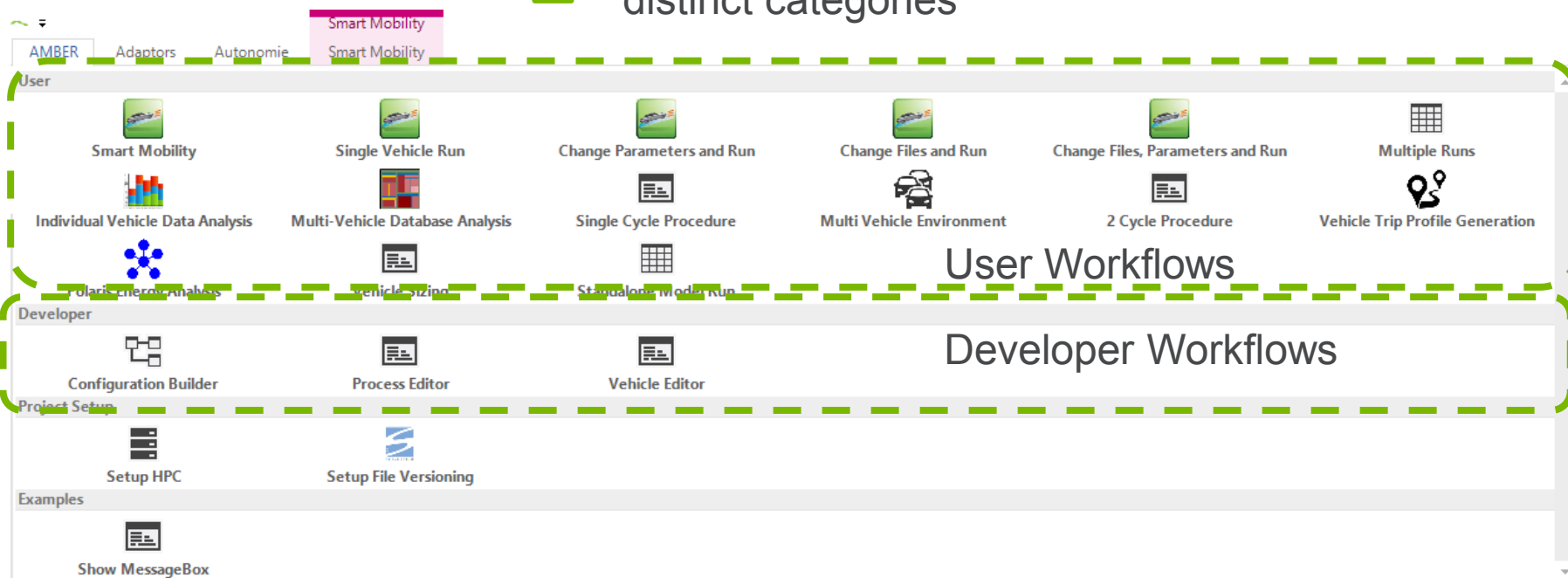


# Technical Accomplishments

## A Diverse Set of Workflows to Support the DOE R&D in a Larger Context



Users and Developer workflows separated into distinct categories



Specific workflows to support specific projects

  
Smart Mobility  
For EEMS

  
Multiple Runs  
For VTO Benefit Analysis

  
Vehicle Editor  
For Component Technology Impacts

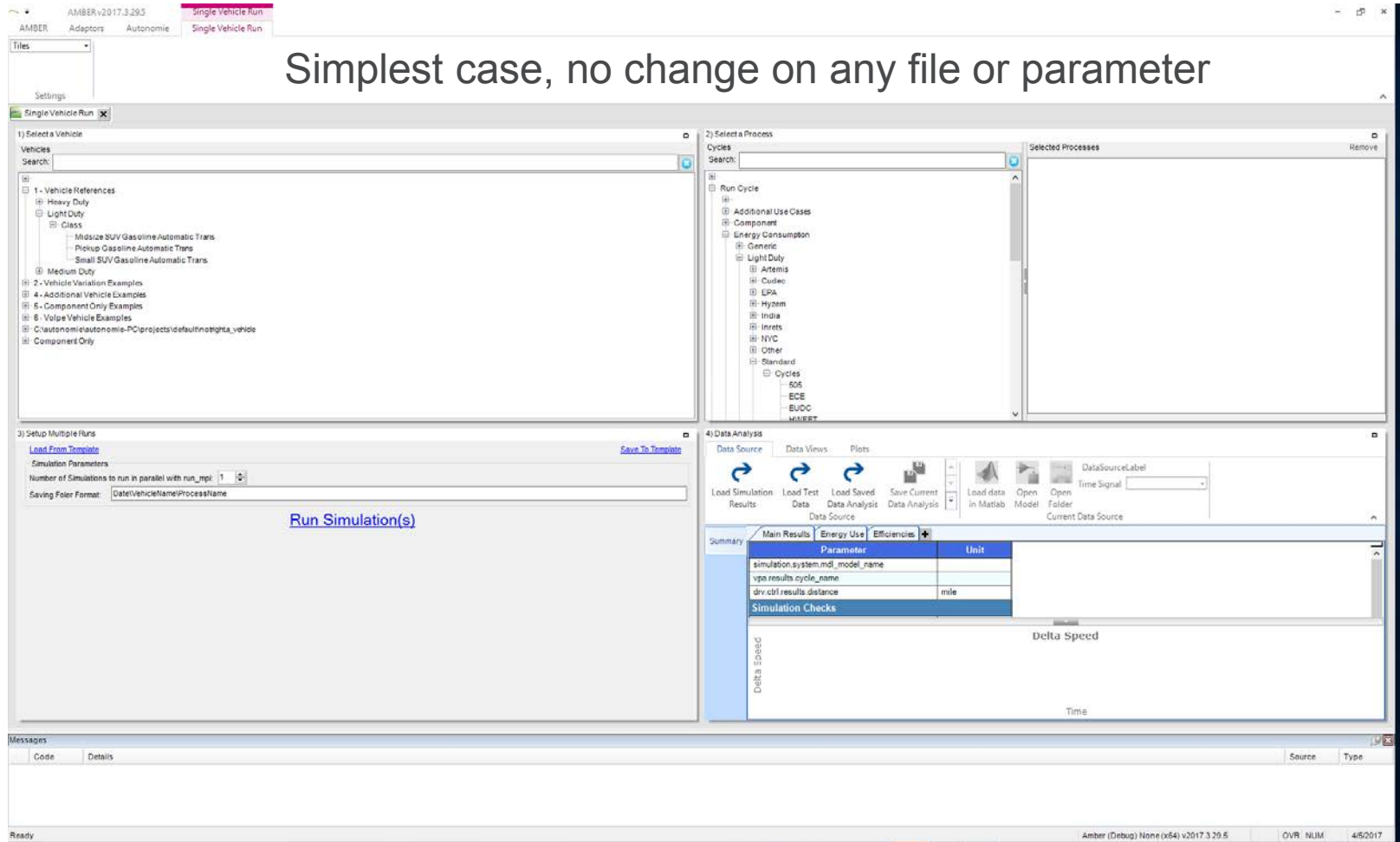
# Technical Accomplishments

For the Same Application, Different Workflows are Provided to Only Show the Information Needed



Select a Vehicle, Select a Cycle Workflow

Simplest case, no change on any file or parameter



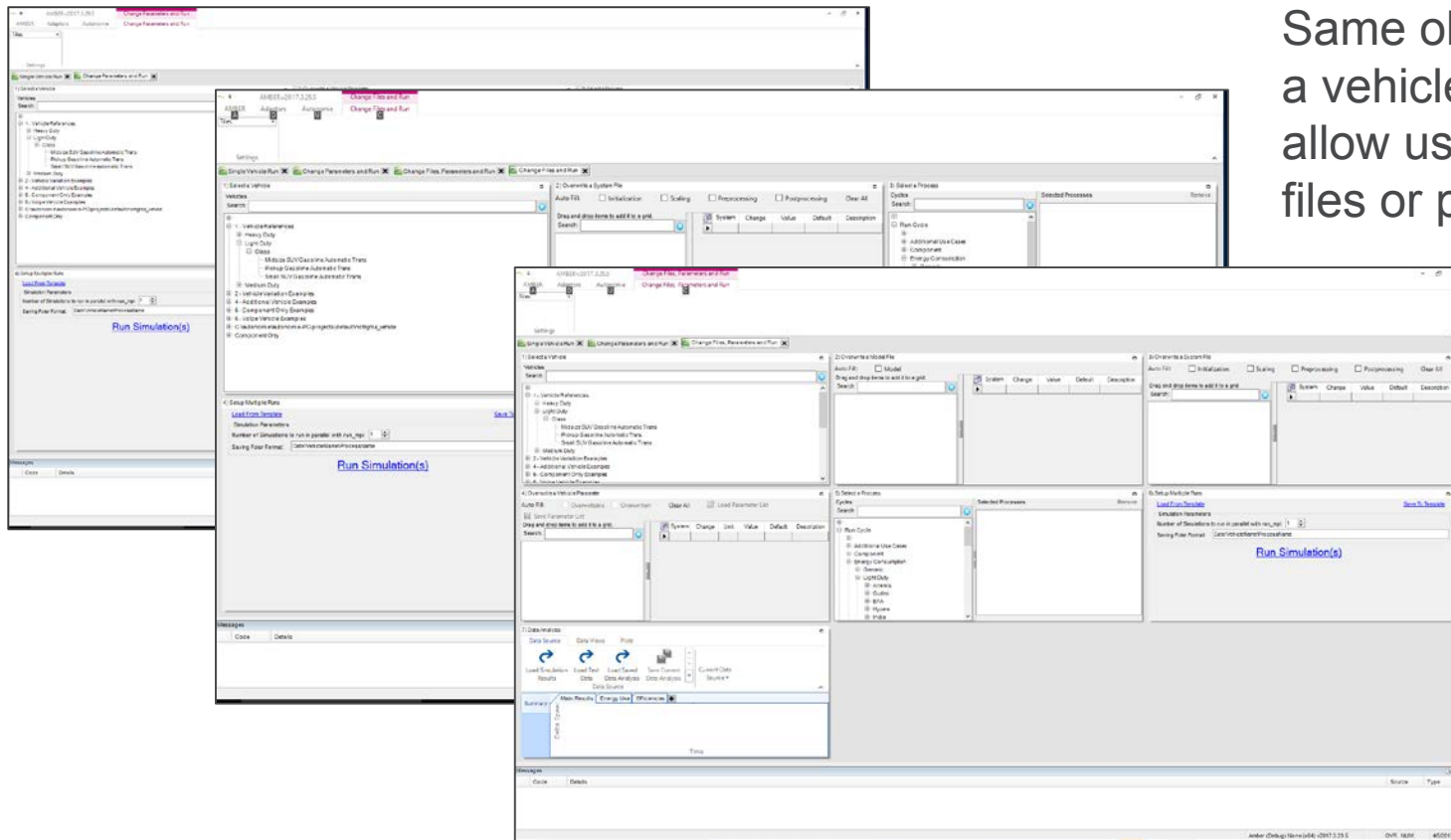
# Technical Accomplishments

## The User Interface Adapts to the Task Complexity



Adaptive UI: Modify Vehicle Parameters , Modify Vehicle Files, Modify Vehicle Parameters and Files

Same objective (simulate a vehicle), but we now allow users to change files or parameters



Simple Tasks Should Have Simple UIs

## Running Large Studies with Autonomie is Now Possible



## Multiple Run Workflow

Multiple Runs

Add Model File

Add System File

Add Parameter

Add Property

Set Auto Fill Changes:

Load template

Save Template

Date\RunNumber\VehicleName\ProcessName

Launch Simulations

Vehicles

Search: HEV

2 - Vehicle Variation Examples

Powertrain

Heavy Duty

Class 6

Series Engine

HEV Series Class6 2wd Additional

Light Duty

Hybrid Electric Vehicle

Integrated Starter Generator

HEV Belt ISG Midsize Gasoline 6

HEV Belt ISG Midsize Gasoline 6

HEV Belt ISG Midsize Gasoline 8

HEV Belt ISG Midsize Gasoline 8

HEV Belt ISG Midsize Gasoline C

HEV Crank ISG Midsize Gasoline

HEV Crank ISG Midsize Gasoline

HEV Crank ISG Midsize Gasoline

HEV Crank ISG Midsize Gasoline

Micro

HEV Micro Hyb Midsize Gasoline

HEV Micro Hyb Midsize Gasoline

HEV Micro Hyb Midsize Gasoline

HEV Micro Hyb Midsize Gasoline

HEV Micro Hyb Midsize Gasoline

Post-Transmission

HEV Parallel Post Trans Midsize A

HEV Parallel Post Trans Midsize

Power Split

HEV Power Split 2x2wd Midsize

HEV Power Split Midsize Diesel

HEV Power Split Midsize Fixed Ra

HEV Power Split Midsize Gasoline

Pre-Transmission

HEV Parallel Pre Trans Midsize Au

HEV Parallel Pre Trans 2 Clutche

Series Engine

HEV Series Midsize Gasoline

HEV Series Midsize Gasoline 2 Sp

Series Fuel Cell

Change Path	Change	Unit	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
veh/drctrl_au	Initialization		HEV Series Class	HEV Belt ISG Mid	HEV Belt ISG Mid	HEV Belt ISG Mid	HEV Belt ISG Mid	HEV Belt ISG Mid	HEV Belt ISG Mid
veh/env/plant	Initialization		drv_ctrl_PI_heavy	drv_ctrl_look_ahe	drv_ctrl_look_ahe	drv_ctrl_look_ahe	drv_ctrl_look_ahe	drv_ctrl_look_ahe	drv_ctrl_look_ahe
veh/vpc/prop	Initialization		env_plant_comm	env_plant_comm	env_plant_comm	env_plant_comm	env_plant_comm	env_plant_comm	env_plant_comm
veh/vpa/eng/plant	Initialization		vpc_prop_ser_en	vpc_prop_par_1m	vpc_prop_par_1m	vpc_prop_par_1m	vpc_prop_par_1m	vpc_prop_par_1m	vpc_prop_par_1m
veh/vpa/accmecch/plant	Initialization		eng_plant_si_220	eng_plant_gasoli	eng_plant_gasoli	eng_plant_gasoli	eng_plant_gasoli	eng_plant_gasoli	eng_plant_gasoli
veh/vpa/tc2/plant	Initialization		accmecch_plant_0	accmecch_plant_0	accmecch_plant_0	accmecch_plant_0	accmecch_plant_0	accmecch_plant_0	accmecch_plant_0
veh/vpa/pumphydra/plant	Initialization		tc_plant_08						
veh/vpa/esshydra/plant	Initialization		pumphydra_plant						
veh/vpa/acchydra/plant	Initialization		esshydra_plant_h						
veh/vpa/mothydra/plant	Initialization		acchydra_plant_s						
veh/vpa/gb/plant	Initialization		mothydra_plant_h						
veh/vpa/gb/ctrl/dmd	Initialization		gb_plant_4_au_3	gb_plant_6_au	gb_plant_6_dct	gb_plant_8_au	gb_plant_8_dct	gb_plant_ct_05_3	gb_plant_ct_05_3
veh/vpa/gb/ctrl/trs	Initialization		gb_ctrl_dmd_n_g	gb_ctrl_dmd_n_g	gb_ctrl_dmd_dct_p	gb_ctrl_dmd_n_g	gb_ctrl_dmd_dct_p	gb_ctrl_dmd_dct_e	gb_ctrl_dmd_dct_e
veh/vpa/vehdym/chas/plant	Initialization		gb_ctrl_trs_au_st	gb_ctrl_trs_au_pa	gb_ctrl_trs_dct_p	gb_ctrl_trs_au_pa	gb_ctrl_trs_dct_p	gb_ctrl_trs_ct_trq	gb_ctrl_trs_ct_trq
veh/vpa/vehdym/fd/plant	Initialization		chas_plant_990_	chas_plant_990_	chas_plant_990_	chas_plant_990_	chas_plant_990_	chas_plant_990_	chas_plant_990_
veh/vpa/vehdym/whl/plant	Initialization		fd_plant_444_acc	fd_plant_247_097	fd_plant_247_097	fd_plant_247_097	fd_plant_247_097	fd_plant_247_097	fd_plant_247_097
veh/vpa/tc/plant	Initialization		whl_plant_0317_	whl_plant_0317_	whl_plant_0317_	whl_plant_0317_	whl_plant_0317_	whl_plant_0317_	whl_plant_0317_
veh/vpa/gen/ctrl/dmd	Initialization		tc_plant_08	tc_plant_25	tc_plant_25	tc_plant_25	tc_plant_25	tc_plant_25	tc_plant_25
veh/vpa/gen/plant	Initialization		gen_ctrl_dmd_alt						
veh/vpa/ess/plant	Initialization		gen_plant_id_2_2						
veh/vpa/accelec/plant	Initialization		ess_plant_pb_66	ess_plant_li_6_7	ess_plant_li_6_7	ess_plant_li_6_7	ess_plant_li_6_7	ess_plant_li_6_7	ess_plant_li_6_7
veh/vpc/brake	Initialization		accelec_plant_20	accelec_plant_20	accelec_plant_20	accelec_plant_20	accelec_plant_20	accelec_plant_20	accelec_plant_20
veh/vpa/cpl/ctrl	Initialization		vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m	vpc_brake_init_m
veh/vpa/cpl/plant	Initialization		cpl_ctrl_au_earlyl	cpl_ctrl_dual_clut	cpl_ctrl_dual_clut	cpl_ctrl_au_earlyl	cpl_ctrl_dual_clut	cpl_ctrl_au_init	cpl_ctrl_au_init
veh/vpa/mot/plant	Initialization		cpl_plant_torqcon	cpl_plant_dual_cl	cpl_plant_torqcon	cpl_plant_dual_cl	cpl_plant_torqcon	cpl_plant_torqcon	cpl_plant_torqcon
veh/vpa/mot/ctrl/trs	Initialization		mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55	mot_plant_pm_55
veh/vpa/pc/plant	Initialization		mot_ctrl_trs_par_	mot_ctrl_trs_par_	mot_ctrl_trs_par_	mot_ctrl_trs_par_	mot_ctrl_trs_par_	mot_ctrl_trs_par_	mot_ctrl_trs_par_
veh/vpa/eng/ctrl/trs	Initialization		pc_plant_095_12	pc_plant_095_12	pc_plant_095_12	pc_plant_095_12	pc_plant_095_12	pc_plant_095_12	pc_plant_095_12
veh/vpa/str/plant	Initialization		eng_ctrl_trs_au_i	eng_ctrl_trs_dct_j	eng_ctrl_trs_au_i	eng_ctrl_trs_dct_j	eng_ctrl_trs_au_i	eng_ctrl_trs_dct_j	eng_ctrl_trs_dct_j
veh/vpa/pc2/ctrl	Initialization								
veh/vpa/pc2/plant	Initialization								
veh/vpa/lmo2/plant	Initialization								



# Technical Accomplishments

## Quantifying the Energy Impact of Smart Mobility using POLARIS Fully Integrated



Smart Mobility

1) Please select the folder location for the Cycle Files: **Real World** Use a directory of time based cycles ☐ Select All

Browse for File Folder:

Cycles Search:

Files	Description
0_10b_rev2.mat	
10_25a1_rev2.mat	
10_25a2_rev2.mat	
10_25b_rev2.mat	
10_25c_rev2.mat	
25_35a_rev2.mat	
25_35b_rev2.mat	
35_rev2.mat	
ARB_Transient.mat	
arb02.mat	
art.mat	
Artemis_extra_urban.mat	
Artemis_hwy.mat	
Artemis_urban.mat	
bus_rte.mat	
cbd_14.mat	
cbd_truck.mat	
cilcc.mat	
cin_hyzauto.mat	
cin_hyzrout.mat	
cin_hyzurb.mat	

2) Select Assignment Type: **Percent Assignment** A randomly selected fraction of cycles assigned to each vehicle.

Vehicles Search: **hev**

Vehicle	Fraction
Compact Gasoline Automatic Trans	
Midsize SUV Gasoline Automatic Trans	0.2
Small SUV Gasoline Automatic Trans	0.2
Pickup Gasoline Automatic Trans	0.2
HEV Crank ISG Midsize Gasoline 6 Speed Auto Trans	0.2

3) Results Path:  C:\autonomie\autonomie-PC\projects\default\results

Name	Unit	Description
------	------	-------------

4) Select the Type of Simulation: **Run Using Cluster** Run the simulations on a cluster using Mathworks Distributed Computing

Name	Value	Unit	Description
------	-------	------	-------------

# Technical Accomplishments

Developers are also Provided Only the Information they Need Through Fast, Streamlined Vehicle Editor



Create a New Vehicle Workflow

## File View

Vehicle Editor

1) Edit Vehicle

Load Vehicle From File Save Vehicle To File Eval Build

VehicleTree

Vehicles

Search:

- 1 - VehicleReferences
  - Heavy Duty
  - Light Duty
    - Class
      - Midsize SUV Gasoline
      - Pickup GasolineA
      - Small SUV Gasoline
  - Medium Duty
- 2 - Vehicle Variation Examples
- 4 - Additional Vehicle Examples
- 5 - Component Only Examples
- 6 - Volpe Vehicle Examples
- C:\autonomie\autonomie-PC\proj
- Component Only

System	Config	Model	Initialization	Scaling
Midsize SUV Gasoline Automatic Trans				
Driver				
Driver block		drv_ctrl_time_based_schedule_look_ahead	drv_ctrl_look_ahead_init	
Environment				
plant		env_plant_earth	env_plant_common	
Vehicle Propulsion Controller				
Vehicle Propulsion Architecture				
Starter				
Controller		str_ctrl_map		
Plant		str_plant_map	str_plant_2_10	
Mechanical Accessory				
Plant		accmech_plant_const_pwr_loss	accmech_plant_0	
Clutch/Torque Converter				
Controller		cpl_ctrl_au	cpl_ctrl_au_earlylckp_6spd_init	
Plant		cpl_plant_torque_converter_map	cpl_plant_torqueconv_over250Nm	
Gearbox				
Plant		gb_plant_au_map_trqloss_funTVratio	gb_plant_6_au_415_234_152_114_086_0_	gb_plant_eff_s
Controller				
demand block		gb_ctrl_dmd_au_eng_veh_spd_accel_pe	gb_ctrl_dmd_n_gen_eng_mot_not_includ	
transient block		gb_ctrl_trs_au_conv	gb_ctrl_trs_au_conv_init	
Energy Storage				
Controller		ess_ctrl_generic_map		
Plant		ess_plant_generic_map	ess_plant_pb_66_6	
Generator				
Controller				
demand block		gen_ctrl_dmd_alternator_map_volt_in	gen_ctrl_dmd_alternator_map_volt_in_init	
constraint block		gen_ctrl_cstr_alternator_map_volt_in		
transient block		gen_ctrl_trs_alternator_map_volt_in		
command block		gen_ctrl_cmd_alternator_map_volt_in		
Plant		gen_plant_alternator_map_volt_in	gen_plant_id_2_2	
Torque Coupling				

# Response to Previous Year Reviewers' Comments

- The reviewer specified Autonomie as having been used worldwide by companies and research organizations and as a true success story of the program.

*We don't seek to replace Autonomie; we are broadening the success of Autonomie to encompass additional simulation tools and transportation research, which did not fit into the natural, vehicle-centric workflow of Autonomie*

# Partnerships and Collaborations

- The decision to replace the previous system simulation framework (Autonomie Plug&Play) was driven by Autonomie's user community (>200 institutions), including Argonne's System Modeling and Control Group.
- The requirements were developed through interactions with the user community
- Numerous meetings have occurred with companies (e.g., Ford, GM...) to make sure that the tool structure was consistent with the requirements
- Specific workflows have been identified to test the capabilities of AMBER before its release

# Remaining Challenges and Barriers

- Develop new processes that are computationally efficient (leverage HPC), cost effective and minimize licensing requirements
- Facilitate integration of new interfaces and tools: many aspects of the graphical user interface will be open
- Continue to provide sufficient flexibility for users

# Proposed Future Research

- Deploy AMBER in FY17 Q4
- Add new use cases to support current and future VTO technologies with focus on Smart Mobility and very large scale simulations
- Define priority list with inputs from users (DOE and Industry), including
  1. Launch Polaris (executable) from AMBER workflow
  2. Initialize specific vehicles (i.e., Ford Focus MY15) using Argonne's new vehicle technology database
  3. Implement Road Runner (multi-vehicles with their environment) workflow
  4. Integrate a Large Scale Study Workflow for VTO benefit analysis including HPC and powertrain sizing
  5. Automated vehicle model development and validation from vehicle test data

Any proposed future work is subject to change based on funding levels

# Summary

## We Can Now Deploy Processes That Were Impossible to Implement Before

- Developed a new software that enable DOE and OEMs to integrate multiple tools into Model Based Engineering Workflows to accelerate technology development and market introduction
- All the vehicle models remain unchanged to ensure backward compatibility (Autonomie application)
- Most of the processes previously integrated in Autonomie Plug&Play have been migrated to AMBER (i.e., single vehicle workflow)
- Several existing processes have been integrated into AMBER (New – Never before done with Autonomie Plug&Play) including large scale simulations (thousands of vehicles) and Smart Mobility (POLARIS/SVTrip/Autonomie)
- First public release planned for FY17 Q4
- Future workflow development will focus on new needs from DOE VTO (I.e., Smart Mobility, Machine Learning...) and our user community

# TECHNICAL BACK-UP SLIDES



# Differences Between Autonomie Plug&Play and AMBER

- Maintaining compatibility between 1.0 and 2.0
  - Vehicles files, the same .a\_vehicle file and xml
  - Model files, the same .a\_model file and xml
  - System .m files, the same .a\_init, .a\_preproc, .a\_postproc, .a\_scale and xml is used
  - Configurations, the same .a\_config and .a\_layout are used,
    - however there are plans to add an option dropping the .a\_layout but retaining the .a\_config. Replacing the .a\_layout would be a .slx or .mdl.
- Processes are different
  - .a\_process file xml is different
  - .a\_run file xml is different
  - Files are assembled through references
- The matlab API is different
  - Units conversion\_calc()
  - Reporting interface to add values to the html report will change
  - Matlab function calls: such as run\_simulation which runs any .a\_run files in the current user folder will be replaced with pxf\_run\_process('name.a\_run')
  - Looking at adding a compatibility layer of functions to expose functionality in a equivalent format.